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(54) Sealed Fluid Swivel Joint

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ABSTRACT OF THE DISCLOSURE

A rotary joint utilizing a single anti-friction bearing interposed between the static and dynamic components wherein a self-aligning or floating seal is utilized to maintain effective sealing in the event of misalignment. The rotary joint includes a bearing supported sleeve to which a conduit adapter may be affixed in such a manner to mount and locate the bearing on the sleeve, and the components are economically manufactured wherein a dependable and efficient rotary joint may be produced at low cost.

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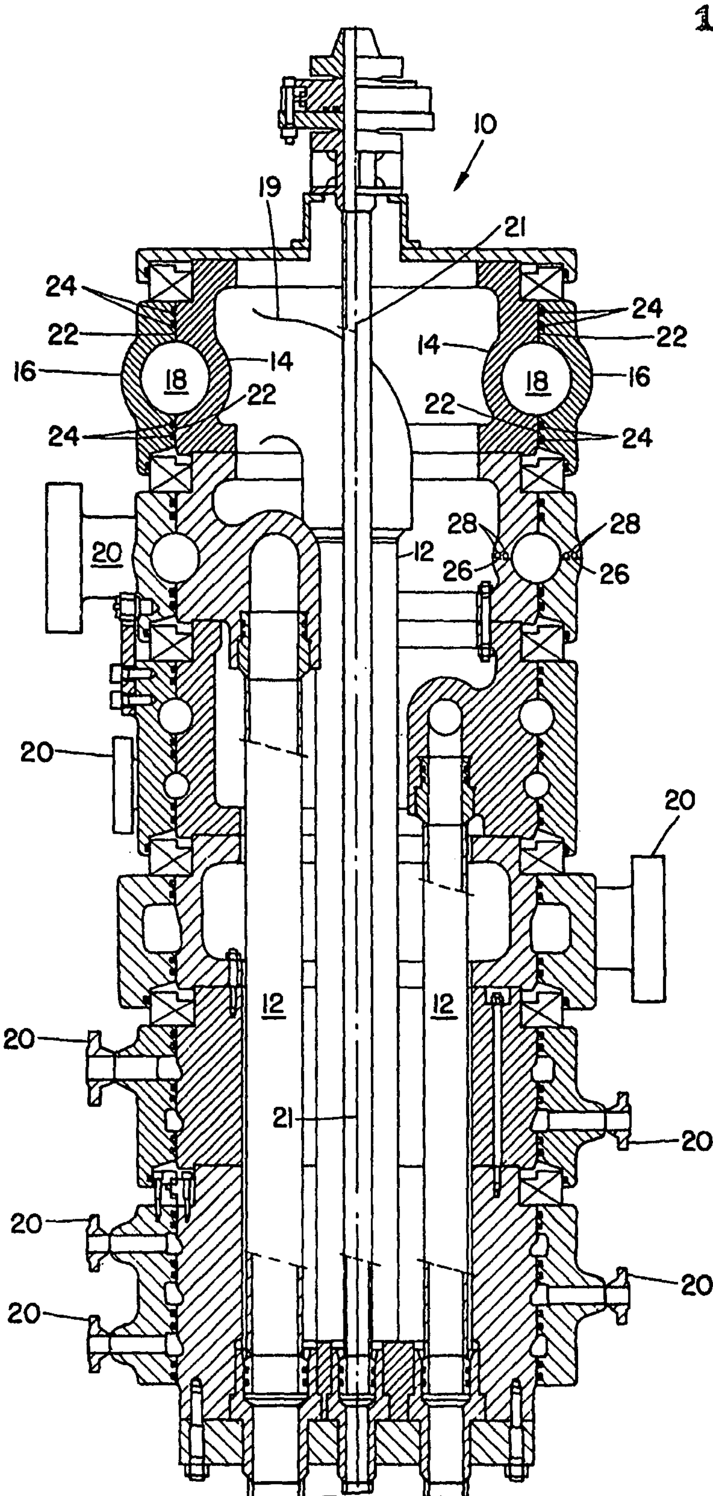

FIG.1

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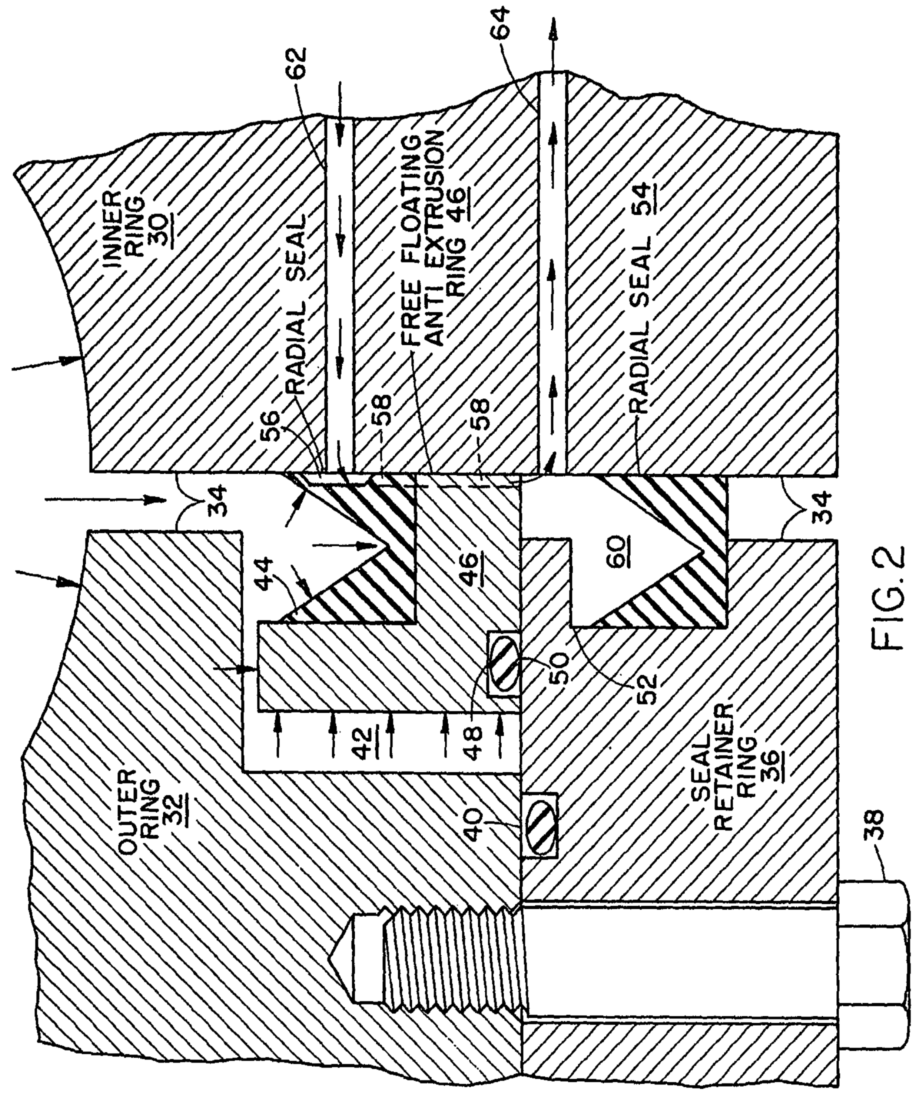

FIG.2

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WHAT IS CLAIMED IS:

1. A sealed fluid swivel joint, comprising:

a. first and second adjacent joint rings which are rotatable relative to each other about a common central longitudinal axis and which define an annular clearance gap therebetween to allow said relative rotational movement between the first and second joint rings, an annular seal housing groove being formed in said first joint ring communicating with said clearance gap;

b. an annular seal positioned in said annular seal housing groove to provide a seal between said first joint ring and said second joint ring, said annular seal including an annular, pliant sealing member, and a rigid annular anti-extrusion ring to prevent the pliant sealing member from being deformed into said clearance gap by a fluid pressure differential existing across said annular seal, said fluid pressure differential biasing said annular sealing member against an adjacent sealing face on said second joint ring to provide an effective fluid seal therebetween; and

c. oil injection means providing a circulating flow of oil intermediate said annular sealing member and the adjacent sealing face on said second joint ring so as to remove generated heat and seal wear debris from the interface between said sealing member and the second joint ring.

2. A sealed fluid swivel joint as claimed in claim 1, wherein said clearance gap is defined between surfaces of said first and second joint rings spaced in a direction perpendicular to the axis of said rotational movement.

3. A sealed fluid swivel joint as claimed in claim 1 or claim 2, wherein said pressure differential existing across said annular seal pressure biases said anti-extrusion ring against said annular sealing member to cause the latter to bear against the sealing face on said second joint ring.

4. A sealed fluid swivel joint as claimed in claim 1, comprising an annular groove formed in the surface of said annular sealing member contacting the adjacent

sealing surface on said second joint ring; circumferentially spaced recesses formed in said annular sealing member and said anti-extrusion ring communicating with said annular groove; an oil inlet passageway in said second joint ring communicating with said annular groove, and oil outlet passageway means in said second joint ring communicating with said recesses and spaced from said annular groove to allow circulating flow of oil through said passageway means, said annular groove and said recesses.

5. A sealed fluid swivel joint as claimed in claim 4, comprising a second annular sealing member intermediate said first and second joint rings proximate the discharge ends of said oil-circulating recesses in said anti-extrusion ring so as to prevent leakage of said oil to atmosphere.

A SEALED FLUID SWIVEL JOINT

The present invention relates to a sealed fluid swivel joint.

The development of subsea petroleum and gas production systems has included a concept wherein a floating processing and storage vessel incorporates as a significant component thereof a high pressure multiple passage fluid swivel joint. The fluid swivel joint includes therein a plurality of stationary fluid passages or pipes extending downwardly from the interior of the joint to carry gas, oil, air, water, or other fluids either up thereto or down therefrom. A plurality of couplings are mounted on the exterior of the fluid swivel joint and are rotatable relative thereto, with each rotatable coupling communicating through the fluid swivel joint with one of the stationary fluid passages or pipes. U.S. Patent Nos. 2,894,268 and 3,590,407 disclose float supported sea terminals utilizing a concept very similar to that described above.

A problem associated with such a fluid swivel joint is in the provision of seals which will withstand the relatively high pressure differentials, often up to 6000 psi (41700 kPa) thereacross, while also providing for the relative rotational movement associated with the swivel joint. The seals which have been utilized in many of these fluid swivel joints have been V-type lip seals, which often resulted in very large frictional forces in the swivel joints when they are designed to accommodate the high pressure differentials.

Additionally, the high pressure differentials have resulted in extrusion of the relatively pliant sealing members into the gaps which they are designed to seal. Prior art swivel joints have often been constructed with an outer ring which rotates about an inner ring with radial seals therebetween. High internal pressures often result in deflections in the rings which increase the radial clearance gap. Common seal materials cannot effectively bridge this gap while maintaining the pressure integrity of the seal.

Therefore, common seal materials have been reinforced with various elements to increase the materials' physical strength in order to bridge the radial clearance gaps. Unfortunately, the reinforcing elements tend to render the seal material compounds less resilient and more abrasive. Consequently, a seal formed of these compounds must have a high contact force in order to effect a seal because the less resilient materials have increased resistance to entry into any microgrooves in the mating seal surfaces so as to seal against any fluid passage. The higher contact stress and the more abrasive nature of the reinforcing elements of the material compounds tend to increase wear of both the seal and the seal mating surfaces, frequently leading to loss of pressure integrity of the seal. In order to solve the problems of extrusion of the seal materials into the gap, the prior art has also utilized anti-extrusion rings of hard plastic or metal to support sealing elements and bridge the clearance gap between the rings of a fluid swivel joint. Unfortunately, these prior art designs have not proved to be totally satisfactory.

In order to ameliorate the problems encountered in prior art seal constructions of this type, GB-A-2132726 discloses improved sealing arrangements for a fluid swivel joint such as are commonly used in offshore loading terminals for tankers. Among various disclosed embodiments is a sealing arrangement which is designed with a bias-loaded anti-extrusion ring or seal to minimize the seal extrusion gap therein. Also disclosed is a sealing arrangement for a fluid swivel joint wherein the components of the seal are relatively free-floating in order to compensate for eccentricity or other variations or distortions in the components of the fluid swivel joint.

According to GB-A-2132726 a sealed fluid joint has first and second adjacent joint rings which are rotatable relative to each other about a common central longitudinal axis. The joint rings have a small annular, ring-shaped clearance gap provided

therebetween so as to allow for relative rotational movement, and one of the rings defines an annular seal housing groove adjacent to the clearance gap. An annular seal is positioned in the seal housing groove and includes an annular pliant sealing member and an adjoining anti-extrusion ring to prevent the pliant sealing member from being extruded into the clearance gap by the relatively high fluid pressure differential existing across the seal. The anti-extrusion ring or the sealing member is biased against an adjacent sealing surface to provide an effective high pressure fluid seal therebetween and also to minimize the extrusion gap existing within the seal. In several embodiments, the swivel joint defines a radial seal configuration having a cylindrically shaped clearance gap extending symmetrically around the central longitudinal axis. In other alternative constructions, the swivel joint defines a face seal configuration having a radially flat-shaped clearance gap positioned symmetrically around the central longitudinal axis.

Moreover, the biasing action is achieved by a spring which is positioned in the seal housing groove so as to bias the annular sealing member against a sealing surface on the second joint ring. In one embodiment, a coil spring is mounted in compression between a wall of the seal housing groove and the annular seal. In another embodiment, a spring extends circumferentially around the annular seal in the annular seal housing groove. In several other embodiments, the spring biases the anti-extrusion ring against the annular sealing member to cause it to bear against a sealing surface on the second joint ring and to also minimize the seal extrusion gap within the seal.

In various of the seal designs, the seal utilizes the pressure differential existing across the seal to pressure bias the annular sealing member against a sealing surface and also to minimize the seal extrusion gap. Other designs allow for the pressure differential to bias the anti-extrusion ring against the annular sealing member to cause it to bear against a sealing surface

on the second joint ring and also to minimize the anti-extrusion gap. In one disclosed embodiment, the pressure differential is utilized to directly bias the annular sealing member against a sealing surface.

In several of the seal designs, the annular sealing member is formed with a V-shaped concave slot therein extending along its annular length to take further advantage of the pressure differential, while in other seal designs, the anti-extrusion ring is constructed with an L-shaped cross-section, and the annular sealing member is positioned between the two legs of the L. In one design, the V-shaped concave slot has its V-shaped opening facing in the direction of the annular clearance gap, while in another the V-shaped opening faces orthogonally away from the annular clearance gap.

Moreover, several multi-element seals are disclosed in embodiments designed to eliminate problems associated with prior art seals of this kind, such as extrusion of the sealing element and unnecessary wear of both the seal mating surfaces. Several of these seal designs include a secondary sealing member positioned intermediate the pliant sealing member and the anti-extrusion ring. In these embodiments, O-rings are positioned between the pliant sealing member and the secondary sealing member and also between the secondary sealing member and the anti-extrusion ring.

The anti-extrusion rings may be constructed of separate pieces or, alternatively, may be an integral component of the seal.

As long as the inner and outer rings of the swivel joint are in a concentric condition relative to each other, the anti-extrusion rings or devices will perform their sealing function in a satisfactory manner. However, operating conditions are encountered at times wherein the inner and outer rings of the swivel joint become eccentric relative to each other, so as to cause any anti-extrusion ring which is composed of plastic material to be either fractured or deformed to the point of becoming ineffective.

Under similar conditions, when the anti-extrusion rings are constructed of metal, they can readily damage the seal surfaces of the inner and outer swivel joint rings as a consequence of their relative eccentricity. Moreover, the eccentricity which may be encountered between the inner and outer rings will cause the non-uniform radial loading of the seal so as to adversely affect the seal pressure integrity, and to produce uneven seal wear tending to result in premature seal failure.

Accordingly, it is an object of the present invention to alleviate or overcome the disadvantages experienced with prior art sealed fluid swivel joints.

The invention resides in a sealed fluid swivel joint, comprising:

a. first and second adjacent joint rings which are rotatable relative to each other about a common central longitudinal axis and which define an annular clearance gap therebetween to allow said relative rotational movement between the first and second joint rings, an annular seal housing groove being formed in said first joint ring communicating with said clearance gap;

b. an annular seal positioned in said annular seal housing groove to provide a seal between said first joint ring and said second joint ring, said annular seal including an annular, pliant sealing member, and a rigid annular anti-extrusion ring to prevent the pliant sealing member from being deformed into said clearance gap by a fluid pressure differential existing across said annular seal, said fluid pressure differential biasing said annular sealing member against an adjacent sealing face on said second joint ring to provide an effective fluid seal therebetween; and

c. oil injection means providing a circulating flow of oil intermediate said annular sealing member and the adjacent sealing face on said second joint ring so as to remove generated heat and seal wear debris from the interface between said sealing member and the second joint ring.

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In the accompanying drawings, Figure 1 is an elevational, sectional view of a known type of fluid swivel joint having a radial type of seal configuration therein; and

Figure 2 is a sectional view to an enlarged scale through a radial type of fluid joint seal according to one example of the present invention.

Referring to Figure 1, there is shown a known type of fluid swivel joint 10 for an offshore loading terminal for tankers, having radial fluid seals therein. A plurality of nonrotatable fluid passages 12, of various diameters, extend vertically within the swivel joint to one of ten different levels therein. Typically, these passages carry gas, oil, air, water, or other fluids either up to or down from the swivel joint 10, at pressures ranging up to 6000 psi (41370 kPa). The uppermost level of the fluid swivel joint is exemplary of the other levels, and includes a relatively stationary, inner joint ring 14 and a rotatable outer joint ring 16. The inner and outer joint rings 14 and 16 define therebetween an annular fluid manifold 18. One of the fluid passages 12 is joined by a coupling 19 through the inner wall of ring 14 to the annular fluid manifold 18, and likewise a coupling 20 (shown for some of the lower levels of the fluid swivel joint) leads from the outer wall of outer joint ring 16. The arrangement is such that a fluid passageway is established from coupling 20, through the fluid manifold 18, to one of the vertical fluid passages 12, while also allowing rotation of coupling 20 and outer joint ring 16 relative to the stationary, inner joint ring 14 and fluid passage or pipe 12. The inner and outer joint rings 14 and 16 have a common concentric longitudinal axis 21, and rotation of the outer ring 16 also takes place about this common axis.

The inner and outer joint rings 14 and 16 define upper and lower small annular clearance gaps 22 therebetween to allow for the relative rotational movements. Figure 1 illustrates a radial type

of swivel joint seal in which the clearance gap 22 forms a generally cylindrical shape. A plurality of annular seals 24 are provided in the clearance gaps 22 to seal the fluid manifold, while also providing for the relative rotational movements.

Fluid swivel joints known in the art may also utilize a second type of fluid swivel joint having a face type of seal configuration, the construction of which is shown generally in dashed lines on the right side of the second highest level of the fluid swivel joint illustrated in Figure 1. In this type of seal, each fluid manifold is defined by an upper joint ring and a lower joint ring, and the clearance gap 26 therebetween is a radially flat-shaped gap extending symmetrically around the common central longitudinal axis 21. In a fluid swivel joint having a face type of seal, the upper and lower joint rings are commonly constructed as separate integral parts which are rotatable relative to each other. A plurality of annular seals 28 are provided in the radially flat gap 26, and these seals function similar to the annular seals 24 previously described.

Known seals of the type shown in Figure 1 generally perform satisfactorily in fluid swivel joints with radial seals as long as the inner and outer joint rings remain concentric. However, any eccentricity of the inner and outer joint rings with respect to each other often results in plastic anti-extrusion rings being fractured or deformed to the point of being ineffective. Metal anti-extrusion rings, on the other hand, can readily damage the sealing surfaces of the inner and outer rings if the rings become eccentric. Moreover, eccentricity often results in nonuniform radial loading of the seal, which can adversely affect the integrity of the seal or cause uneven seal wearing, thus resulting in premature seal failure.

Referring to Figure 2, the swivel joint shown therein is designed to compensate for any eccentricity in the outer joint rings 30, 32 and to prevent undesired extrusion of the seal into the radial clearance gap 34 defined between the rings. A seal retainer

ring 36 is secured in place by a plurality of bolts 38, and an O-ring seal 40 seals the two components relative to each other. The seal retainer ring 36 and outer ring 33 together define an annular seal housing groove 42 adjacent to the clearance gap 34. The annular seal includes a first annular, pliant sealing member 44 which has a V-shaped slot communicating with the gap 34 and which is located between the limbs of an L-shaped anti-extrusion ring 46. The lower surface of the anti-extrusion ring 46 defines an annular groove 48 for housing an O-ring 50, to provide a seal between the anti-extrusion ring 46 and the seal retainer ring 36. The anti-extrusion ring 46 is free-floating and is initially displaced from the inner joint ring 30 by a relatively small seal extrusion gap.

In operation, the internal pressure is transmitted through clearance gap 34, and above radial seal 44 and anti-extrusion ring 46 to the outer side of the anti-extrusion ring, such that the pressure differential across the seal presses the anti-extrusion ring against the outer diameter of the seal member 44, and against the outer surface of inner ring 30. Moreover, a clearance is provided between the outer diameter of the anti-extrusion ring 46 and and the inner diameter of the seal housing groove 42 which allows for limited eccentric horizontal movements of the outer ring 32 relative to the inner ring 30 without adversely affecting the radial loading of the sealing element 44.

The internal pressure acting on the outside diameter of the anti-extrusion ring 46 deflects the latter inwardly towards the inner joint ring 30, and thereby reduces the seal extrusion gap. As a result, an increasing internal pressure will reduce the seal extrusion gap to thereby alleviate any problem of seal extrusion.

An oil injection system, which operates under a low pressure, is employed to cool the seal and remove seal wear debris from the seal lip area, and operates as follows:

Oil is injected into the seal structure through the inlet passageway 62 in the inner joint ring 30, flows into and circulates within annular groove 56 in the sealing member 44, flows downwardly through recesses or grooves 58 in the sealing member and the anti-extrusion ring 46, and enters annular space 60 between the retainer ring 36 and the inner joint ring 30 after the formation of an oil film on the interfaces between the anti-extrusion ring 46 and inner joint ring 30. A sealing member 54 in the space 60 prevents leakage of the oil to atmosphere, and forces circulation of the oil through an oil outlet passageway 64 in the inner joint ring 30. The heat which is generated by the friction of the sealing member 44 and anti-extrusion ring 46 against the surface of the inner joint ring 30 is transmitted to the injected circulating oil. After leaving the outlet passageway 64, the oil may be filtered and cooled prior to being recirculated through the seal arrangement by means of a suitable circulating pump (not shown).

Thus, the oil injection system primarily serves the purpose of removing heat and seal wear debris, although it also provides some minor degree of lubricity to interfacing components.

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